Detection of Mixed Phase Top: Preliminary report

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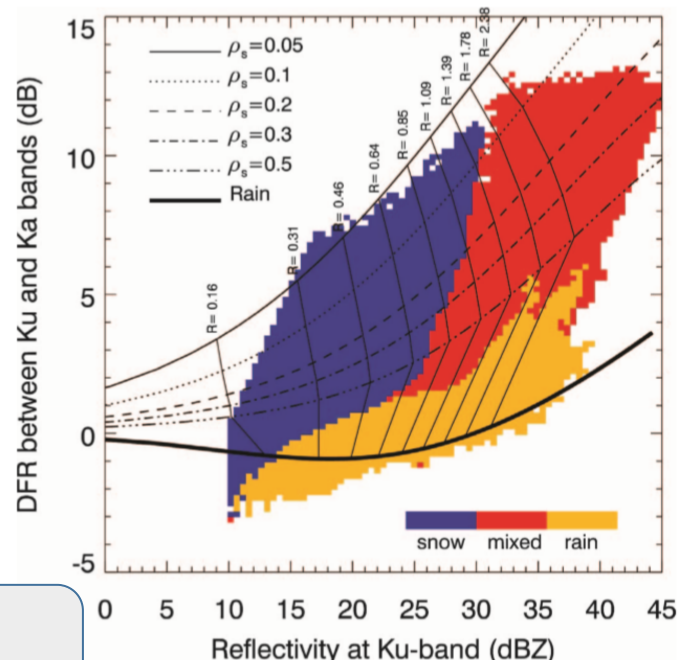
Need for identifying the phase transition height (PTH)

- PTH is important in microphysics of precipitation system.
- PTH is an important parameter in rain retrieval algorithms for radar and radiometer.
    - Basic algorithm flow of PR and DPR
        - 1. Zm -> Ze: Attenuation correction to have accurate Ze at both Ku and Ka. k-Ze relation.
        - 2. Ze -> R: Conversion from Ze(Ku and/or Ka) to R. R-Ze relation.
    - Both steps need information on phase state of precipitation and PSD.
    - Attenuation correction is based on the H-B method and SRT.
        - PIA estimate from Zm (PIA_HB) is compared with PIA estimate from SRT (PIA_SRT), and PSD parameters are adjusted to make them agree.
        - To calculate PIA_HB from Zm profile, we need to assume k-Ze relationships (at Ku and Ka band) that depend on the phase state and PSD.
            - Need to assume the phase state of precipitation at each height.
            - The transition height of phase state in convective storm is not known
    - PSD estimate obtained by attenuation correction is used to convert Ze into R

Idea behind the algorithm

- The combination of DFR and Ze(Ku) can be used to identify the phase state of precipitating particles.
- But, DFR cannot be accurately estimated because it needs accumulated attenuation correction.
- Derivatives of DFRm depend only on the local specific attenuations that can be estimated from Zm(Ku) which is almost attenuation free down to the phase transition height.



(Liao and Meneghini, 2016)

If Z_e and Z_m are expressed in dB units,

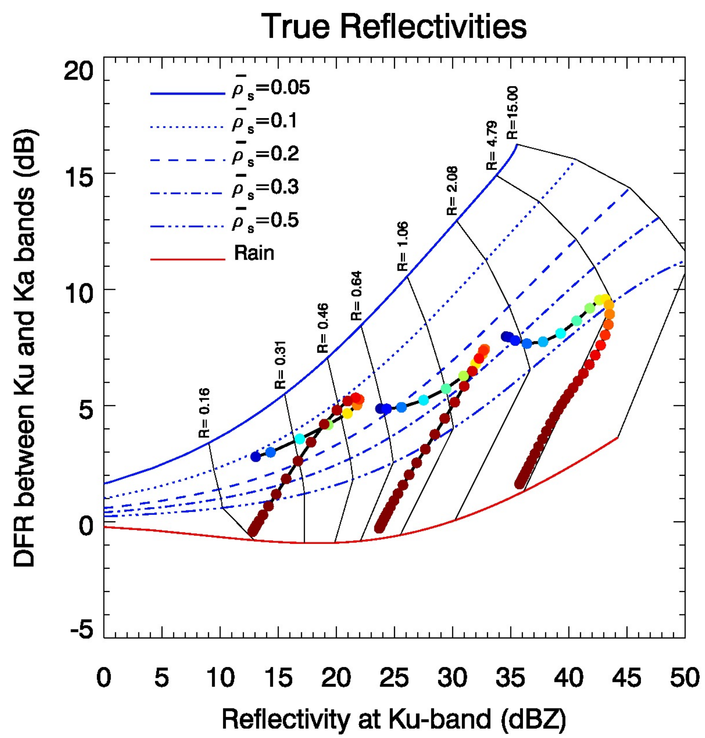
$$Z_e(r) = Z_m(r) + 2\int_0^r k(s)\,ds$$

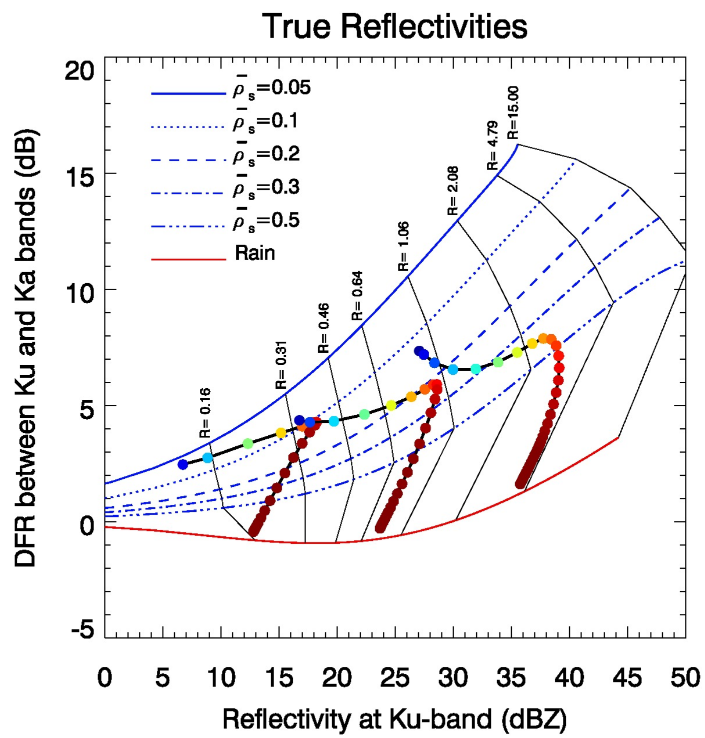
$$\frac{Z_e(r)}{dr} = \frac{Z_m(r)}{dr} + 2k(r)$$

$$\mathrm{DFR}(r) = Z_{e,Ku}(r) - Z_{e,Ka}(r)$$

$$\mathrm{DFR}_m(r) = Z_{m,Ku}(r) - Z_{m,Ka}(r)$$

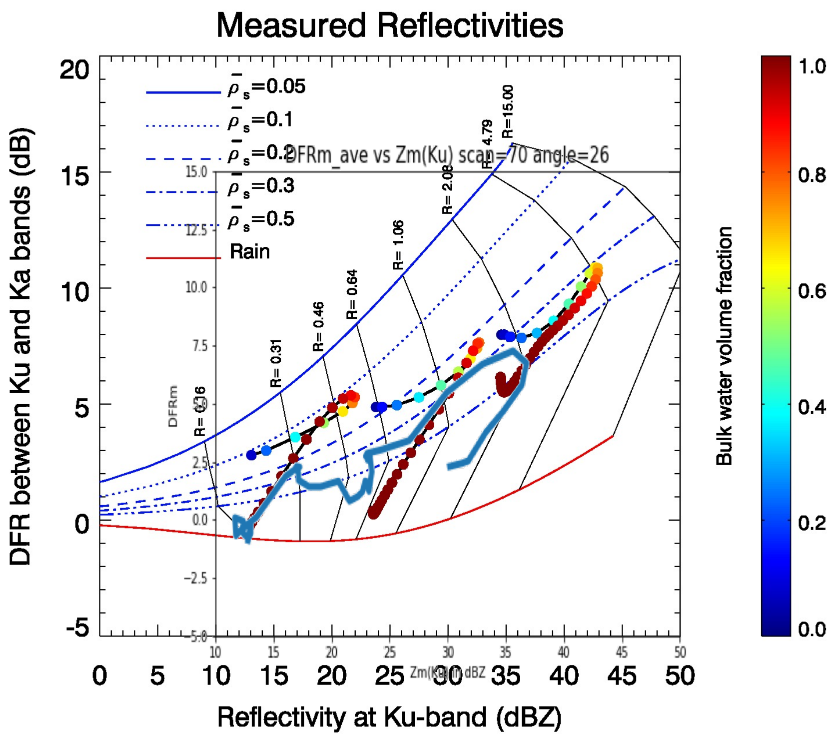
$$\frac{\mathrm{DFR}(r)}{dr} = \frac{\mathrm{DFR}_m(r)}{dr} + 2(k_{Ku}(r) - k_{Ka}(r))$$





Trajectories of radar signatures of melting snow beginning from dry snow, partially melting to melted snow (rain) following the melting layer model that imposes a constant mass flux (or equivalent rainfall rate) in the vertical column, i.e., N(D)V(D) is unchanged from snow, melting to rain. As such, the M-P rain DSD is converted from rain to snow and melting layer. From the left to right three curves represent equivalent precipitation rates of 0.16, 0.85 and 5 mm/h., respectively. Note that PSD in terms of melted sizes are changed along the vertical because of differences in their velocities.

Same as the left plot but for the case in which the same DSD is assumed along the column. As such, a constant rain rate is not preserved but liquid water content does, which is opposite to the left plot. Note that the results shown on the left are the combined effects of both changes in dielectric constant during melting and differences of fall velocities during changes of phase. The results, shown in this plot, reflect the changes in dielectric constant alone.



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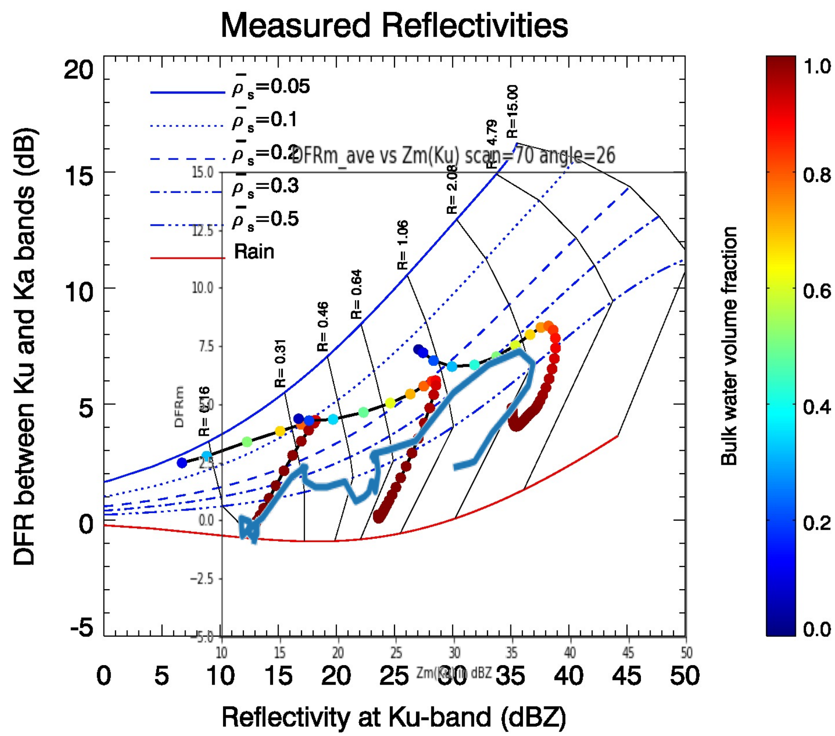

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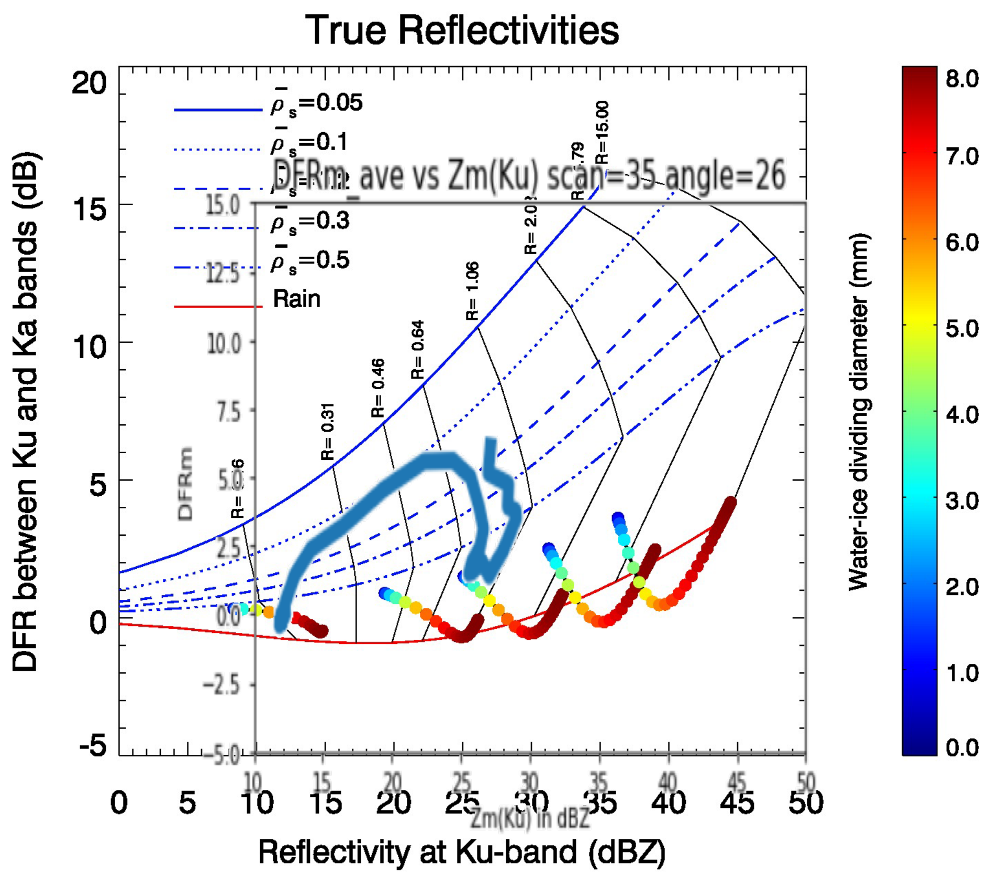
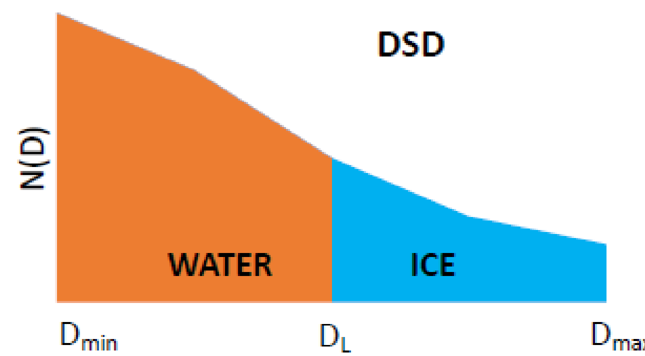


Precipitating particles are assumed to be **liquid** as their diameters are less than D_L and **ice** when their sizes are larger than D_L. D_L is the diameter (melted) that separates water and ice particles in the particle size spectrum, defined as the water-ice dividing diameter. As the particle size distribution follows the M-P distribution, the radar reflectivity factor is given by

$$Z = C\int_{D_{min}}^{D_L} N(D)\sigma_{water}(D)dD + C\int_{D_{min}}^{D_L} N(D)\sigma_{ice}(D)dD.$$

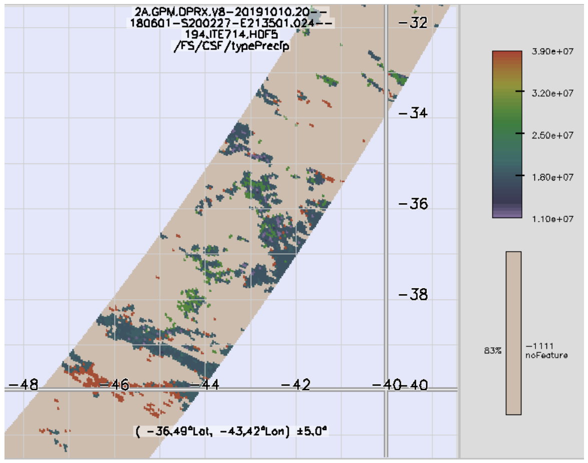
The color curves shown on the left reveal the results of DFR and Ku-band reflectivity obtained from above equation. Each curve represents a constant D_m and color denotes value of D_L.

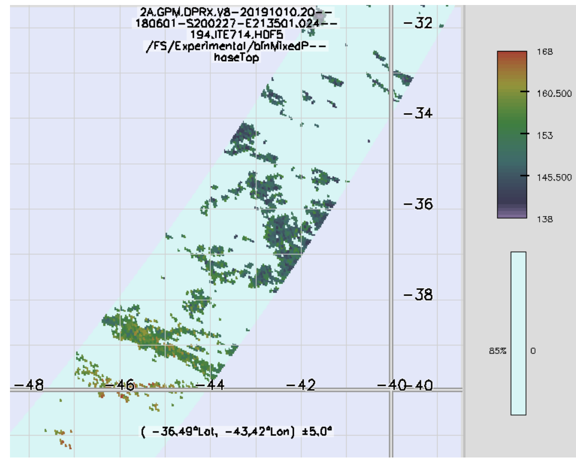


Algorithm

- Find the height where DFR changes most with range (height).
  - DFR is estimated from DFRm (measured apparent DFR) with little attenuation correction.
  - Calculate the second derivative of DFR wrt range
  - Find the maximum of its absolute value within the pre-defined interval around the 0 deg. C.
- Advantage
  - Very simple
  - No dependence on the calibration
  - It works even when no BB is detected.
- Disadvantage
  - Susceptible to noise
  - Depend on the 0 deg. C height estimates

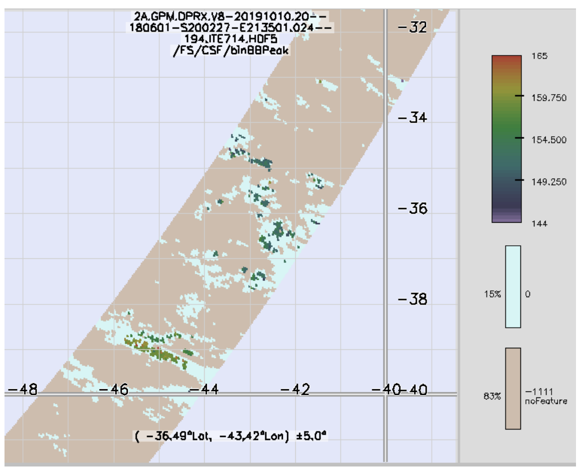
typePrecip

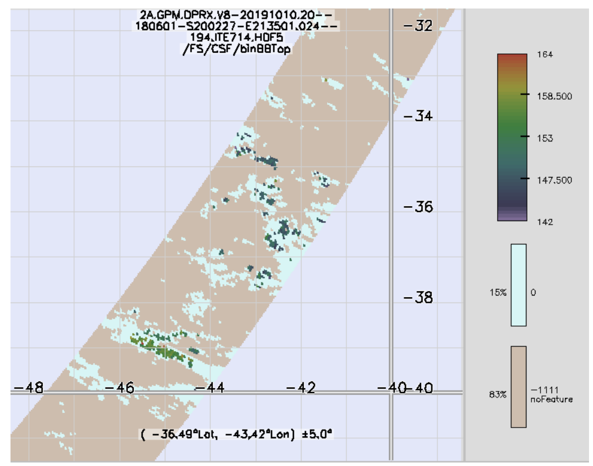




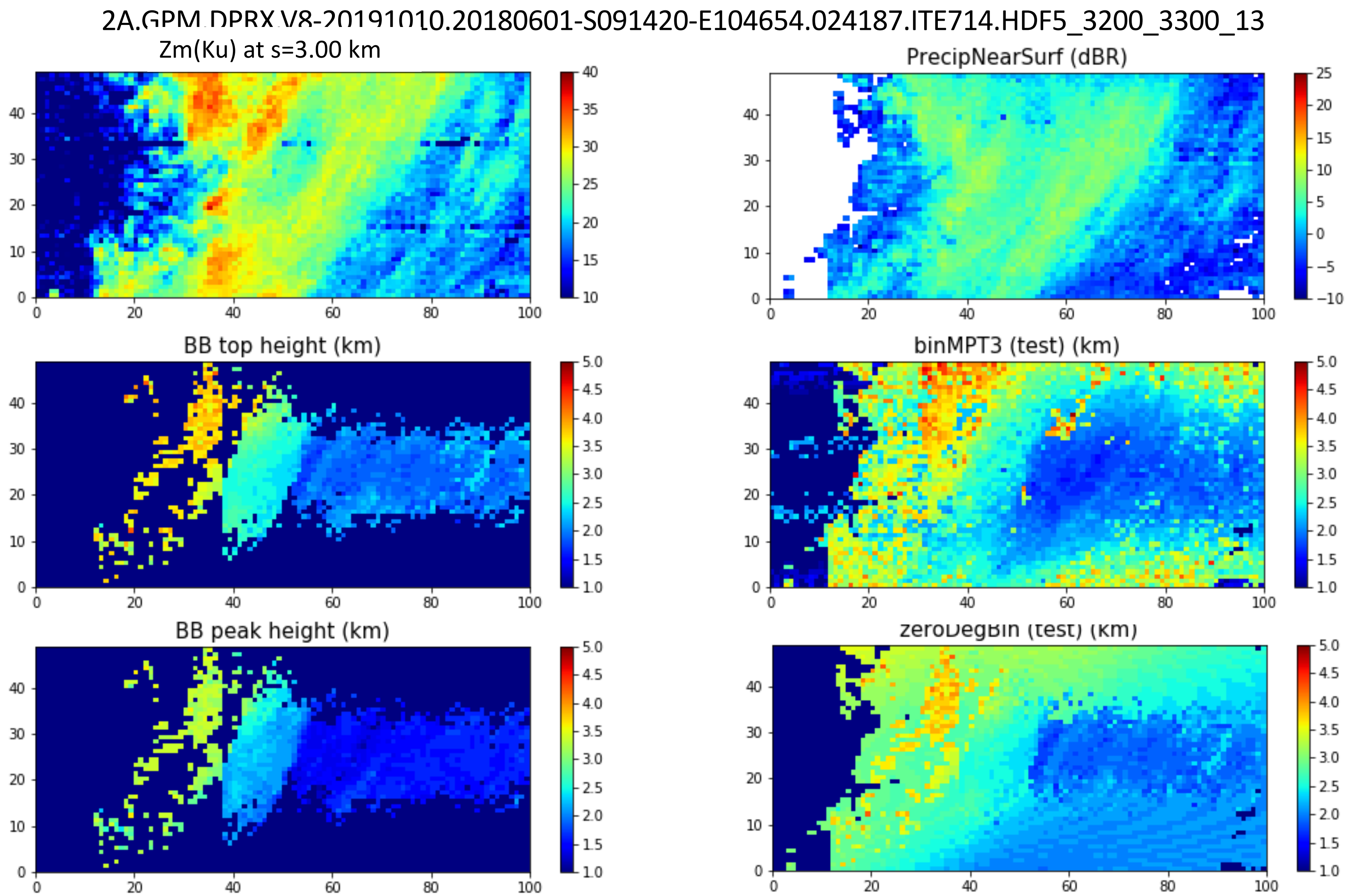
binMixedPhaseTop

binBBPeak

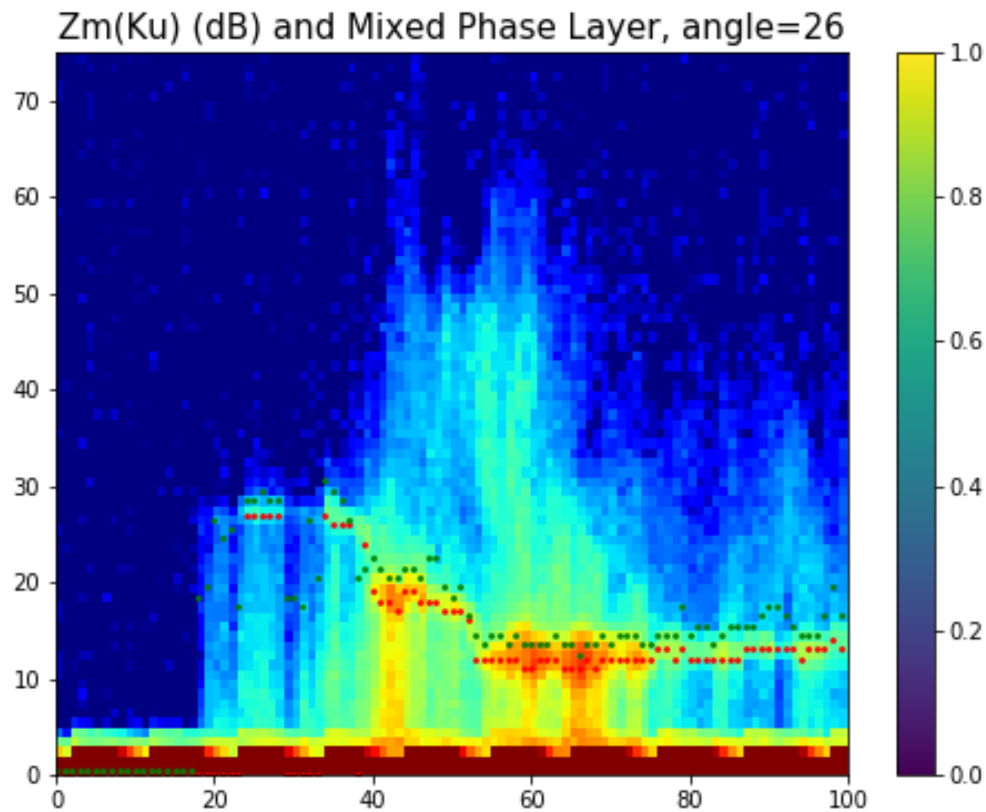




binBBTop


2A.GPM.DPRX.V8-20191010.20180601-S091420-E104654.024187.ITE714.HDF5_3200_3300_13
Zm(Ku) at s=3.00 km
PrecipNearSurf (dBR)
BB top height (km)
binMPT3 (test) (km)
BB peak height (km)
zeroDegBin (test) (km)
0 20 40 60 80 100
0 10 20 30 40
10 15 20 25 30 35 40
−10 −5 0 5 10 15 20 25
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0

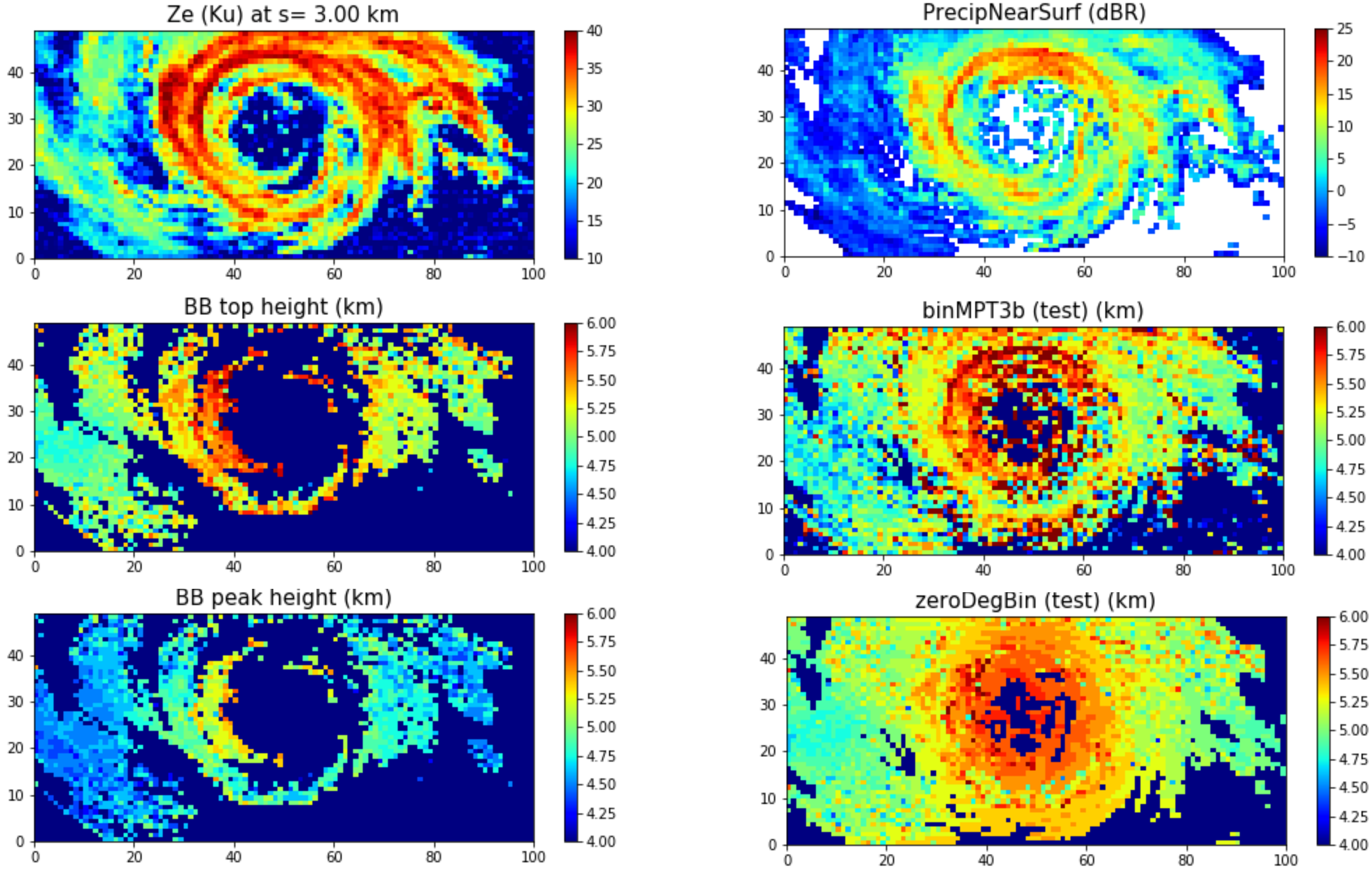
2A.GPM.DPRX.V8-20191010.20180601-S091420-E104654.024187.ITE714.HDF5_3200_3300_13



Red: BB Peak
Blue: BB Top
Black: MPT (V6X)
Green: MPT(test)

Dorian: 2A.GPM.DPR.V8-20191010srt.20190904-S100351-E113624.031343.ITE716.HDF5_2650_2750_09

Zm(Ku)



Summary

- A new variable, binMixedPhaseTop, is introduced as an experimental output variable in V6X of DPR dual-frequency product.
- binMixedPhaseTop assigns a bin of MPT in almost all raining pixels.
- binMixedPhaseTop agrees reasonably well with binBBTop when BB is detected.
- binMixedPhaseTop seems to give a reasonable height of the melting layer in stratiform rain pixels even when BB is not detected.
    - Some angle bin dependence due to the smearing effect near scan edges.
- binMixedPhaseTop in convective rain pixels is erroneous and unreliable. Further study is necessary.
- The current parameters used in this algorithm give rather noisy output and need improvement and adjustment even for stratiform rain.